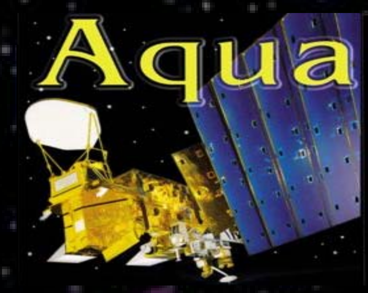
Validation of Satellite AIRS Retrievals with Aircraft NAST-I Soundings and Dropsondes

– Implications for Future Satellite Sounding Capabilities



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Empirical Orthogonal Function (EOF) NAST-I/AIRS Regression Retrieval

For clear sky and opaque cloud:

$$R = \varepsilon_{s,c} B_{s,c} \tau_{s,c} - \int_{P_{ac}}^{P_{s,c}} B\,d\tau - (1 - \varepsilon_{s,c})\,\tau_{s,c} \int_{P_{s,c}}^{0} B\,d\tau^*$$

Radiance EOF Amplitudes

$$C_i = \sum_{j=1}^{nc} R_j E_{ji}$$

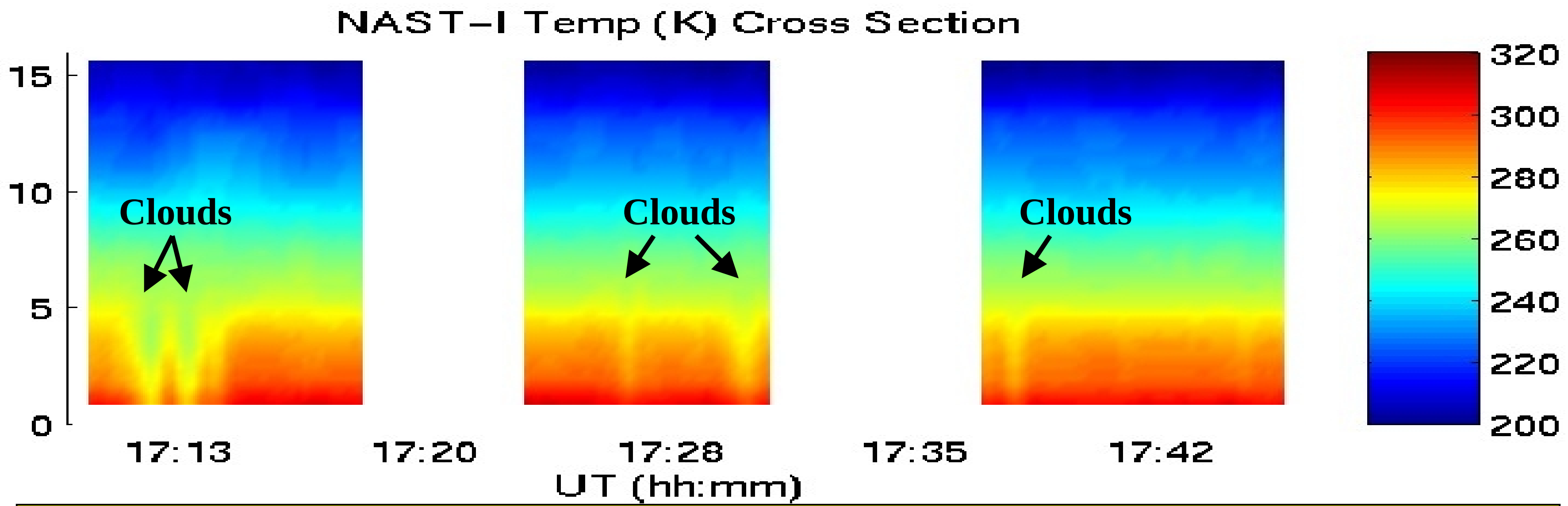
$$\left.\begin{matrix} \mathbf{T_s}, \\ \boldsymbol{\varepsilon_s(\nu)}, \\ \mathbf{T(p)}, \\ \mathbf{Q(p)} \end{matrix}\right\} = \sum_{i=1}^{n-1} K_{mi} C_i + K_{mn} P_s$$

<u>Retrieval Solution</u>

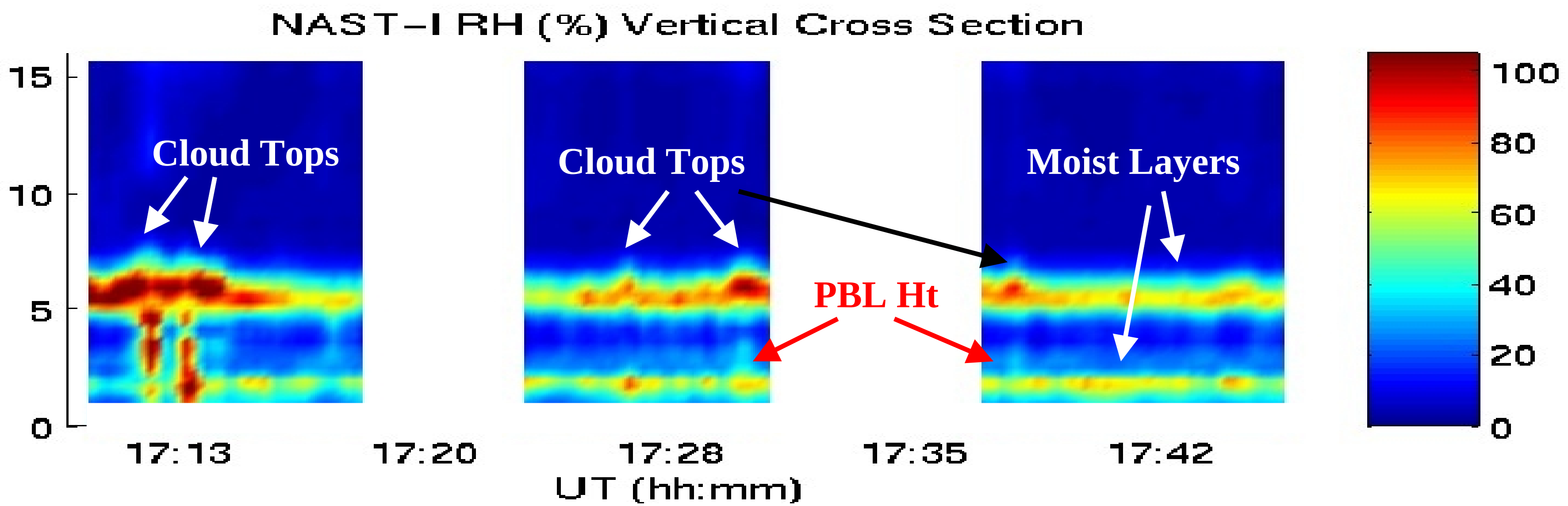
R = radiance
$\varepsilon_{s,c}$ = surface or cloud emissivity
$B_{s,c}$ = surface or cloud Planck radiance
τ = transmittance between aircraft and atmospheric Pressure level (P)
$\tau_{S,c}$=atmospheric transmittance between aircraft and surface or cloud ($P_{S,c}$)
τ^* = atmospheric transmittance between surface or cloud P and aircraft
P_{ac} = aircraft pressure, P_s = surface pressure
$\Re$ = radiance
E = radiance covariance EOFs
C = radiance EOF amplitudes
T = temperature
Q = H_2O mixing ratio
K = regression coefficients

- **Physical Regression – EOFs and regression training based on calculated radiances**
- **Training includes cloud, sfc emissivity, sfc skin temp, and solar variability effects**
- **Null radiance errors assumed for PC specification and regression training**
- **EOF # selected by spatial radiance RMSD (observed minus retrieval) minimization**

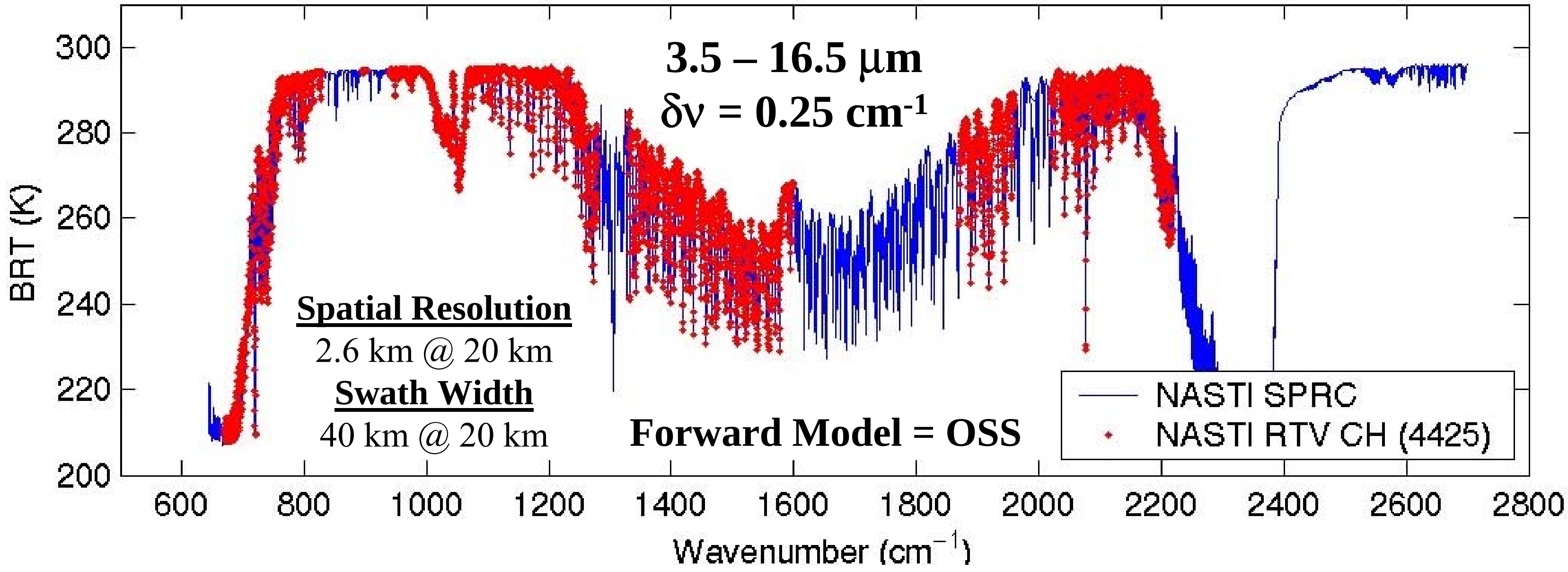
Cloud Effects on Retrieval

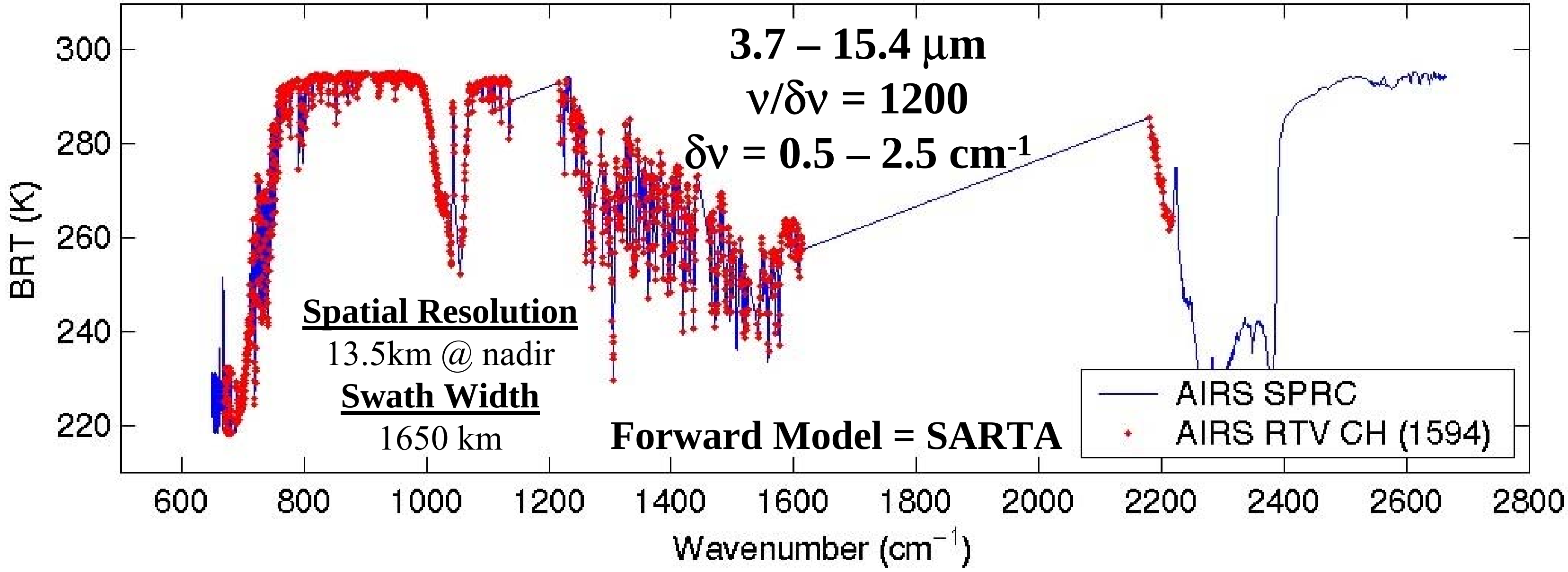


NAST I-HOP (June 12, 2002) Three Adjacent Flight Legs Over Oklahoma

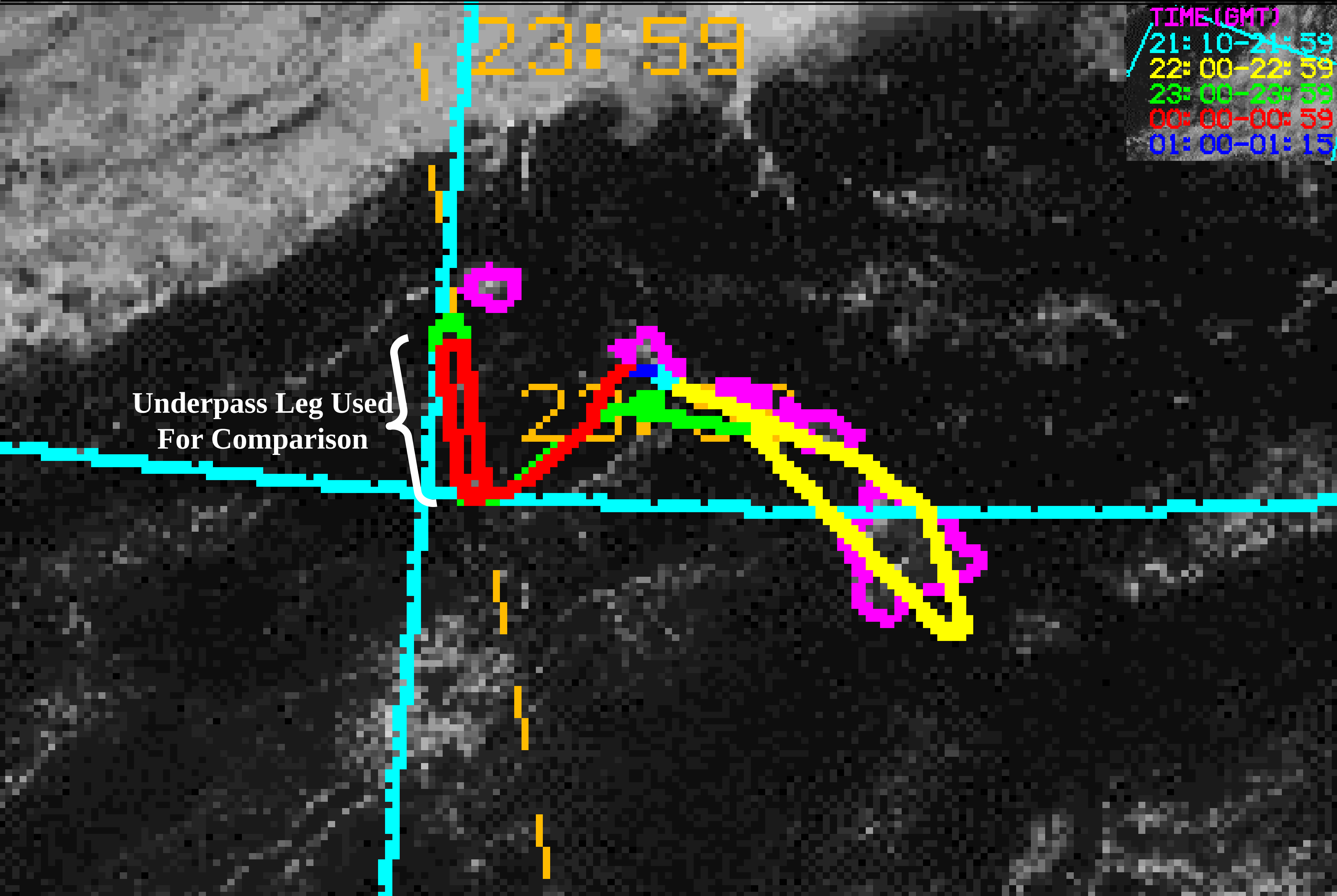


NAST-I and AIRS Spectra and Retrieval Channels

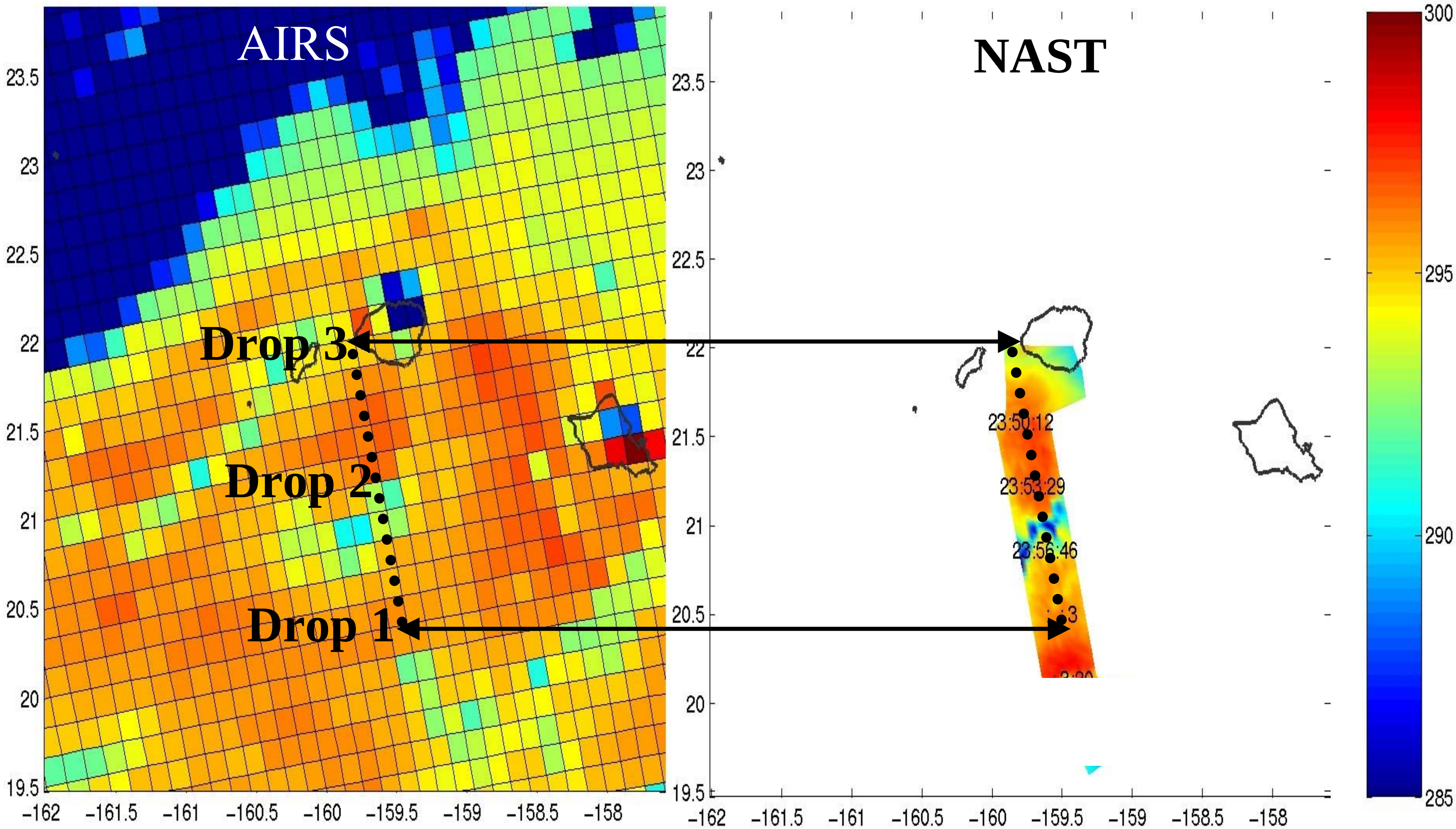




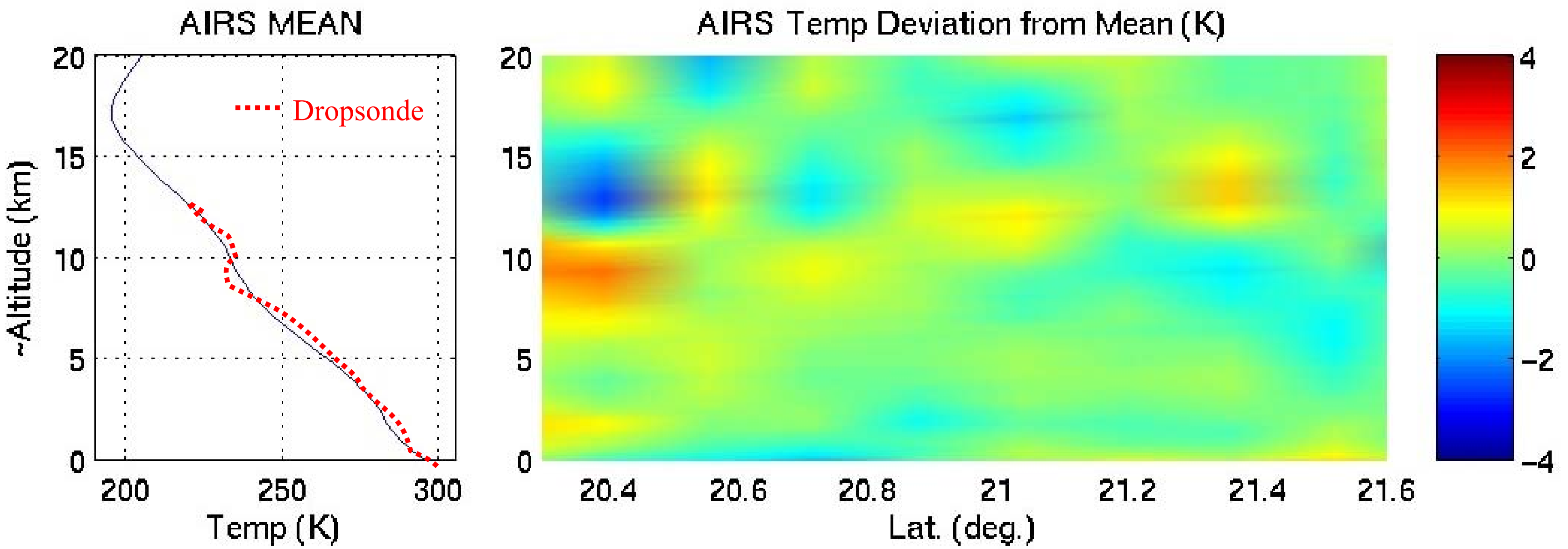
Aqua Overpass Flight (March 3, 2003)



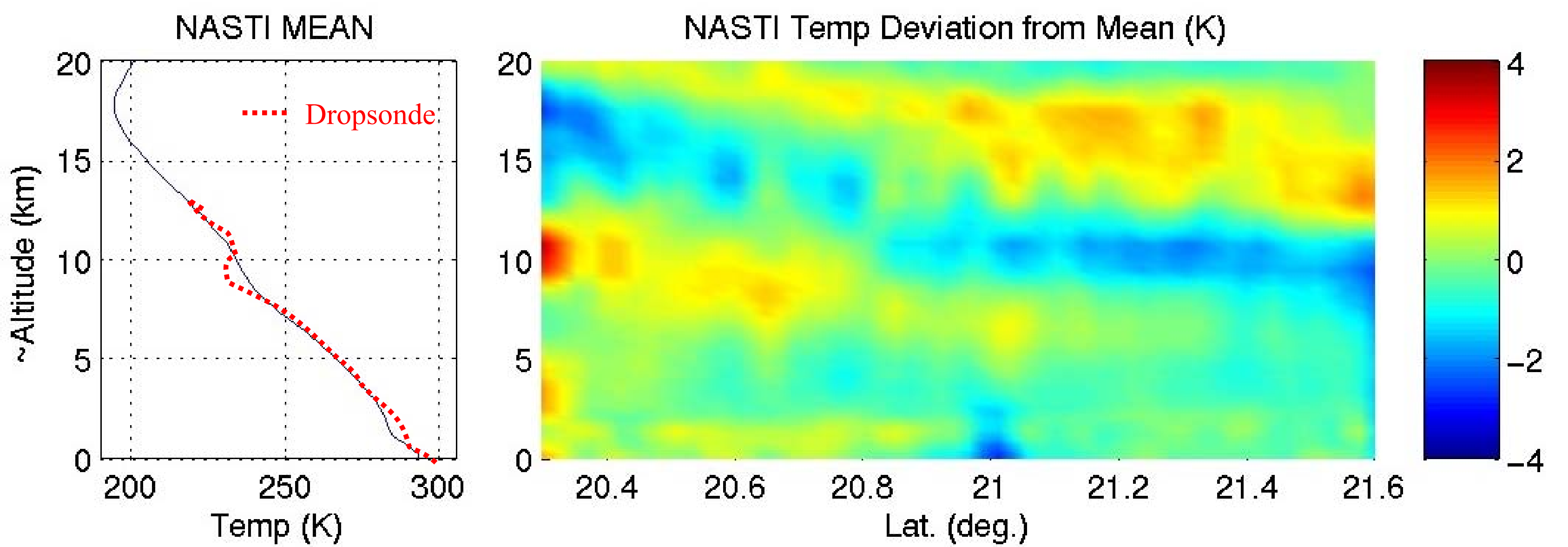
AIRS, NAST, Dropsondes Used for Intercomparison



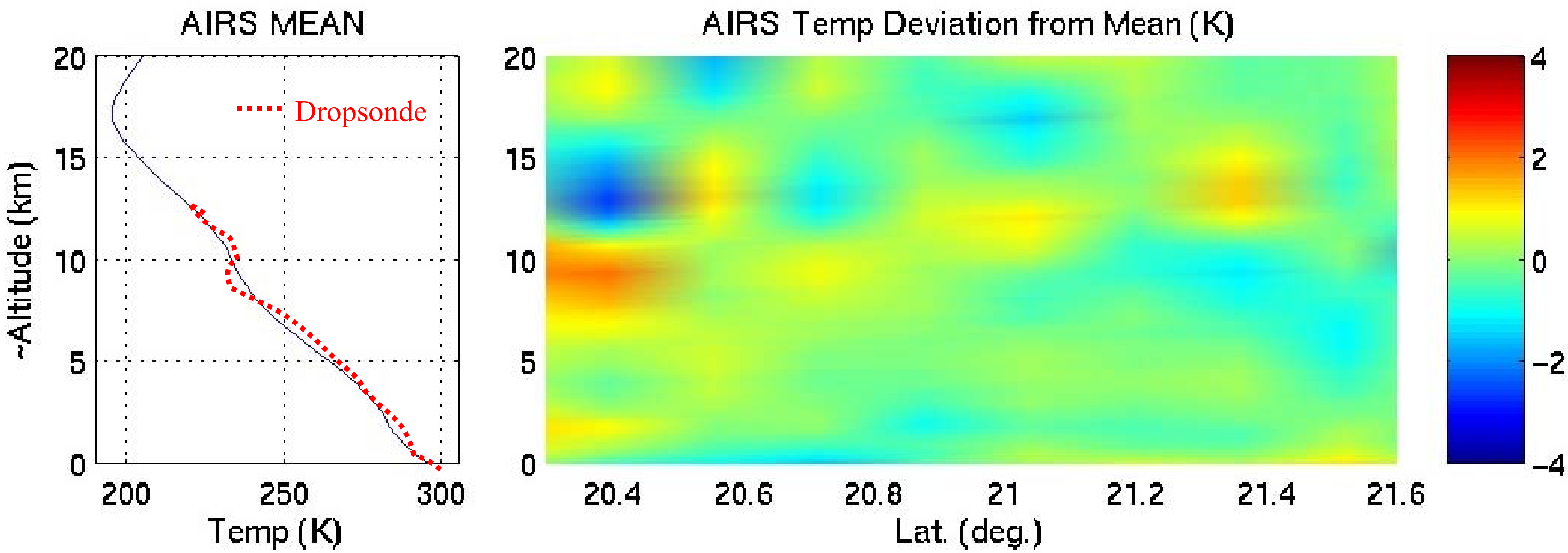
Retrieval Comparisons (Full Resolution AIRS vs NAST)



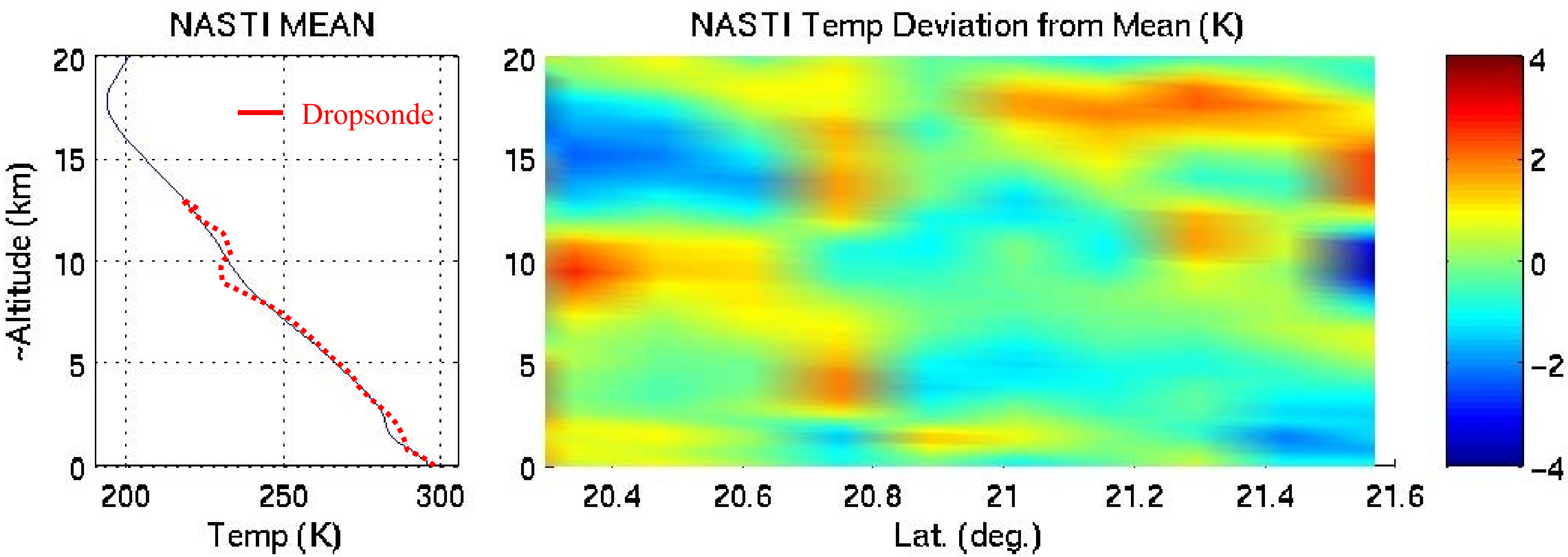
Some Differences in fine scale structure but spatial average is in good agreement



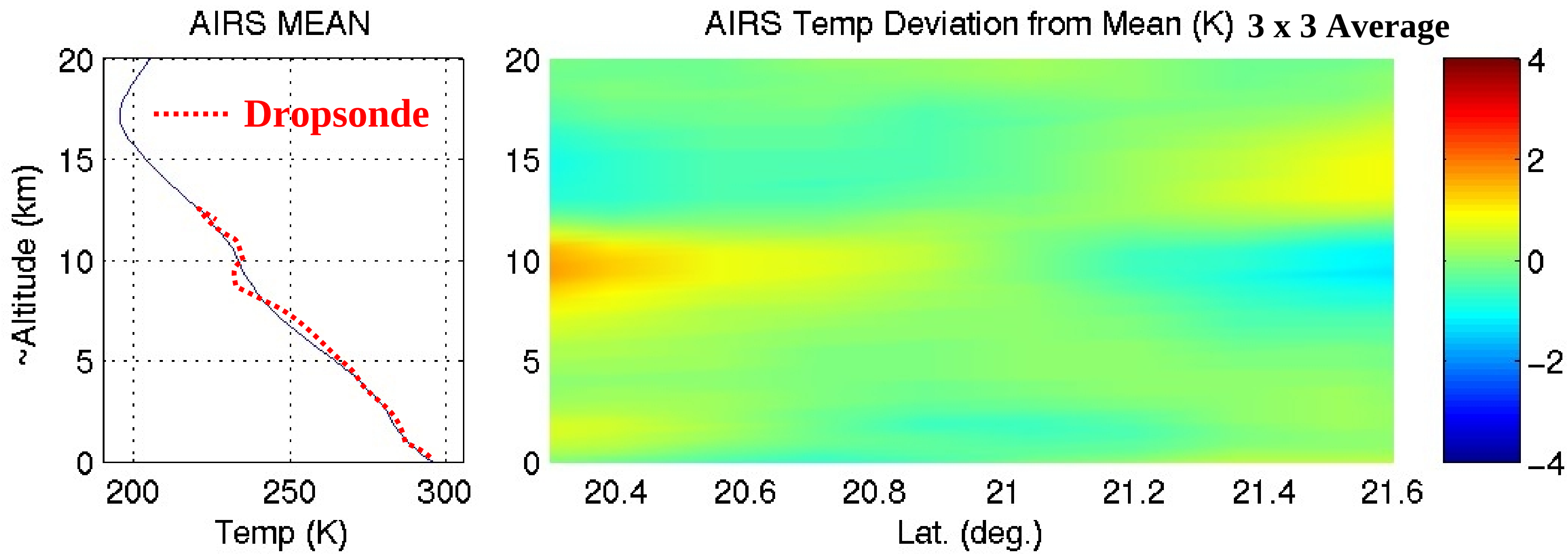
AIRS vs NAST (with AIRS noise added)



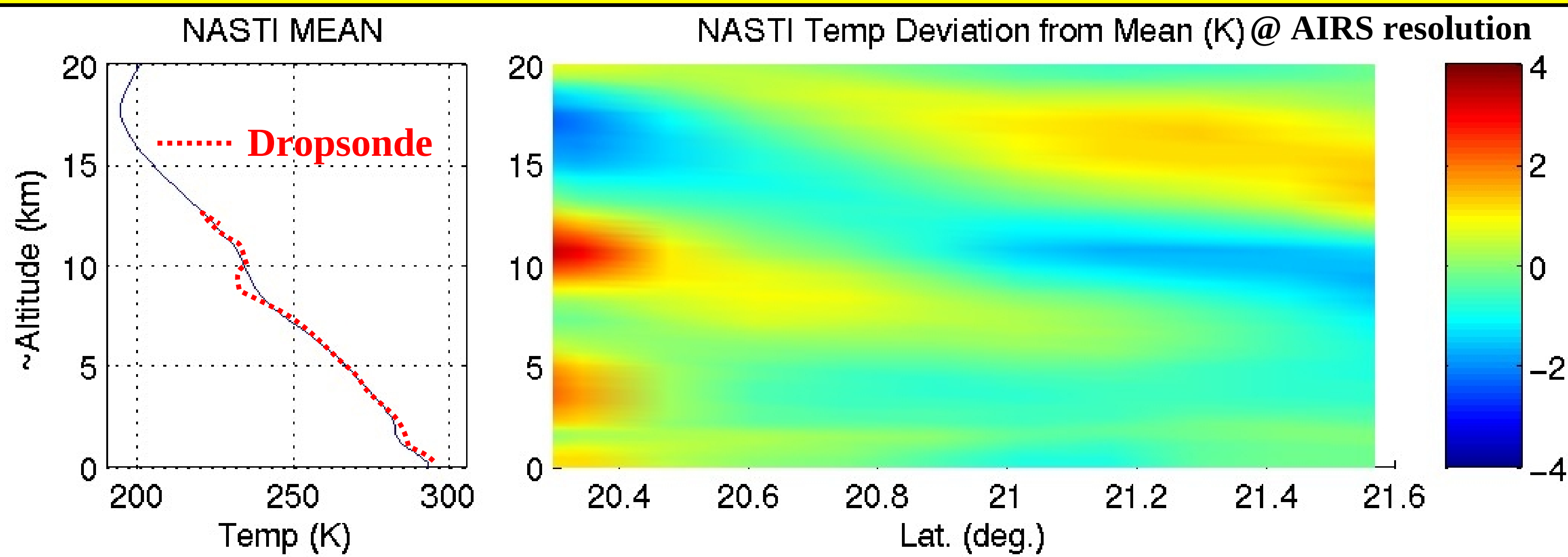
AIRS level single sample noise upsets spatial continuity of small scale vertical features



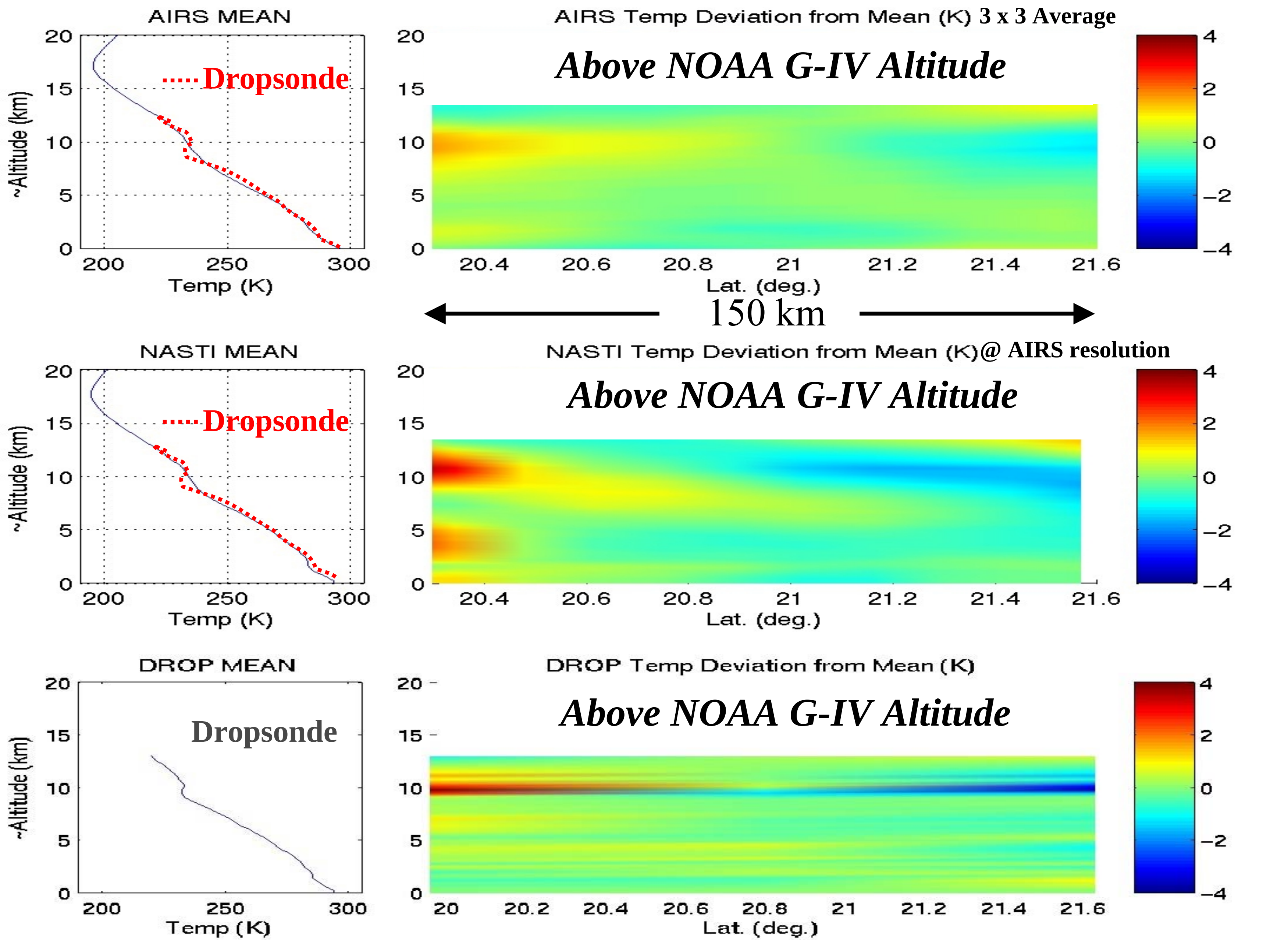
3 x 3 AIRS Average Vs NAST & Dropsonde Cross-sections



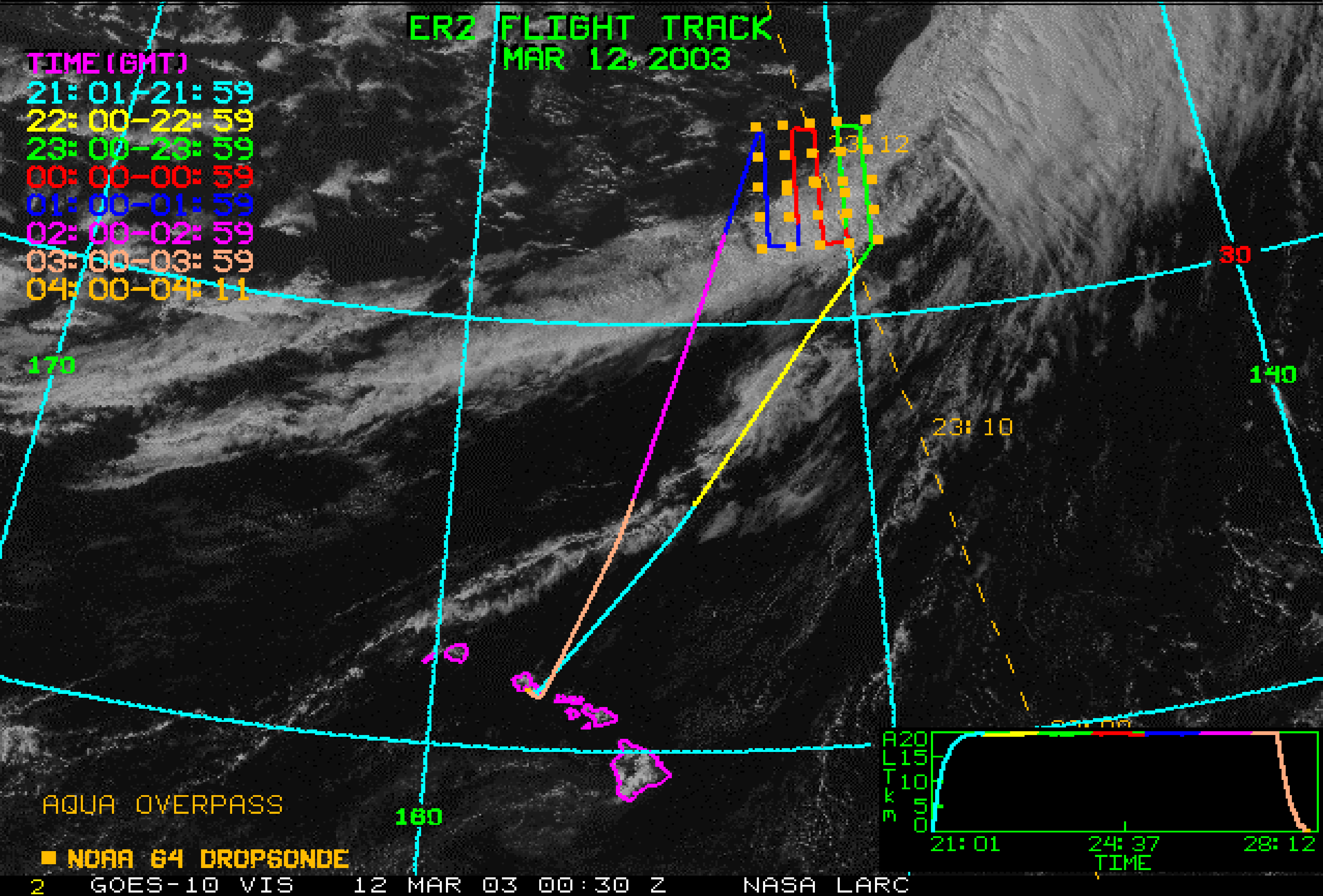
Vertical structure radiance signal is small; retrieval requires small spectrally random noise



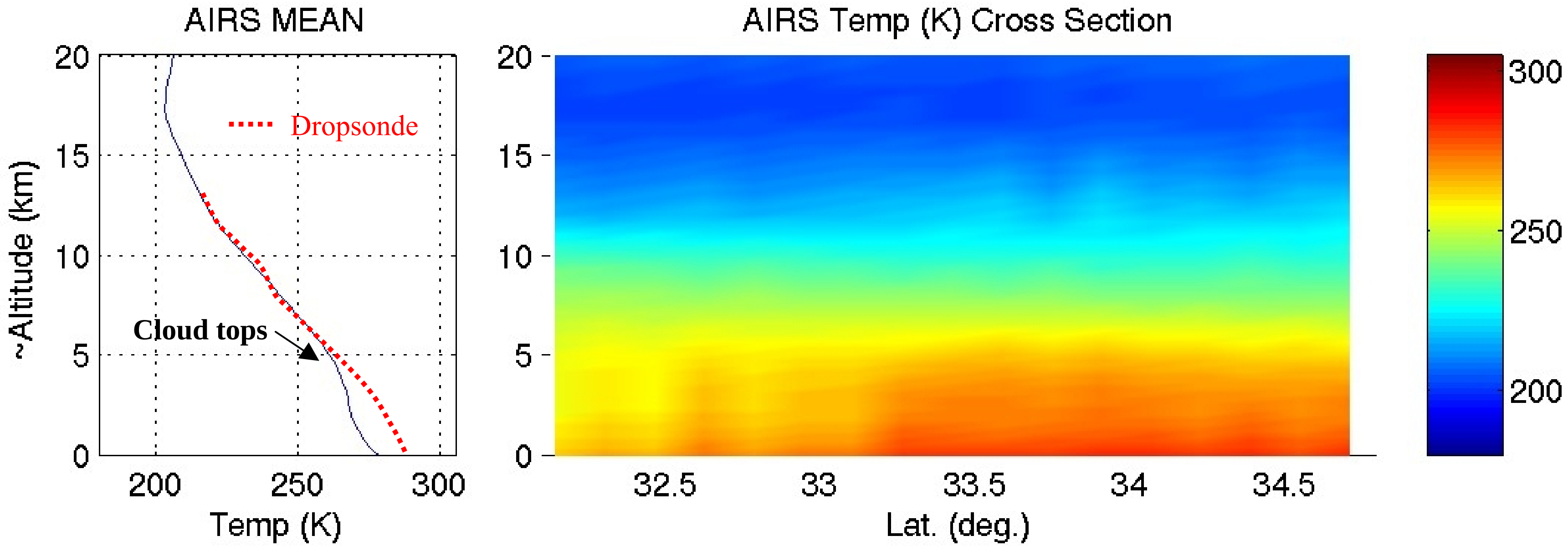
3 x 3 AIRS Average Vs NAST & Dropsonde Cross-sections

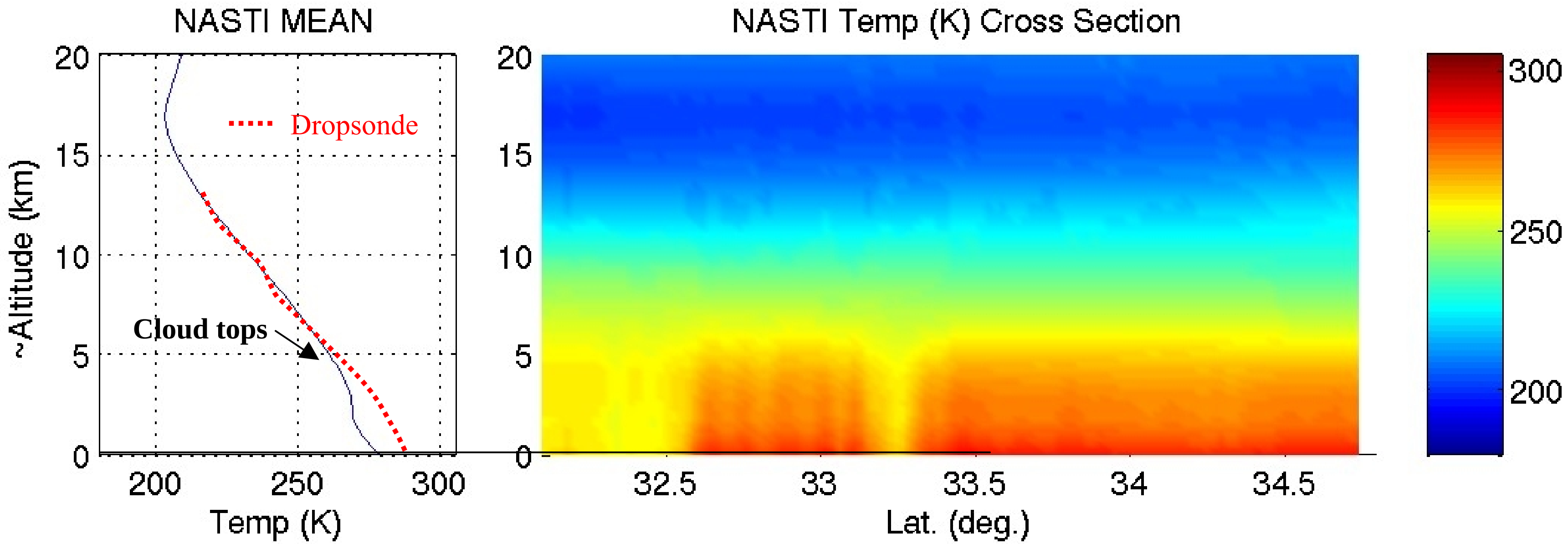


Aqua Overpass Flight (March 11/12, 2003)

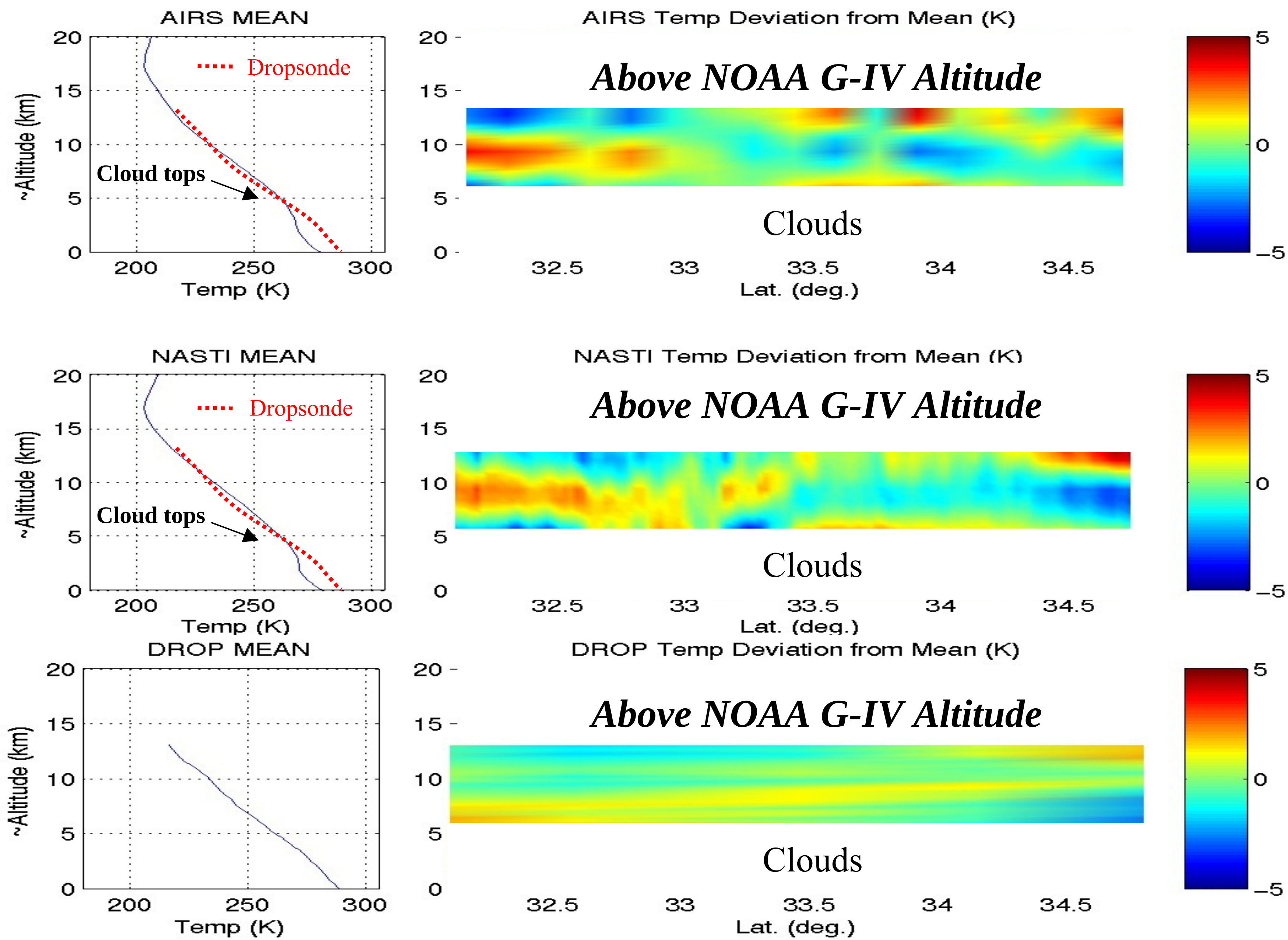


Temperature (March 11/12, 2003)

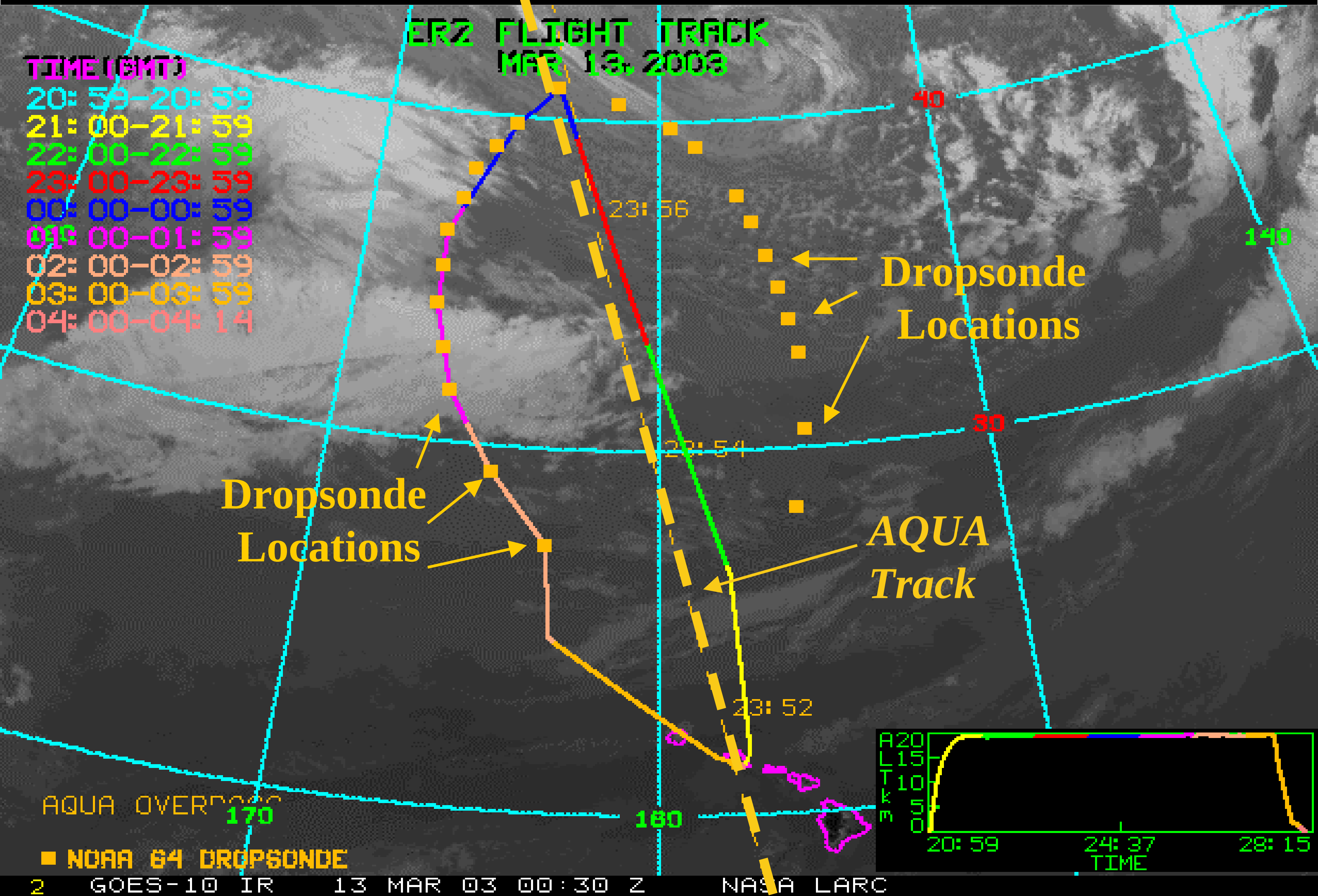




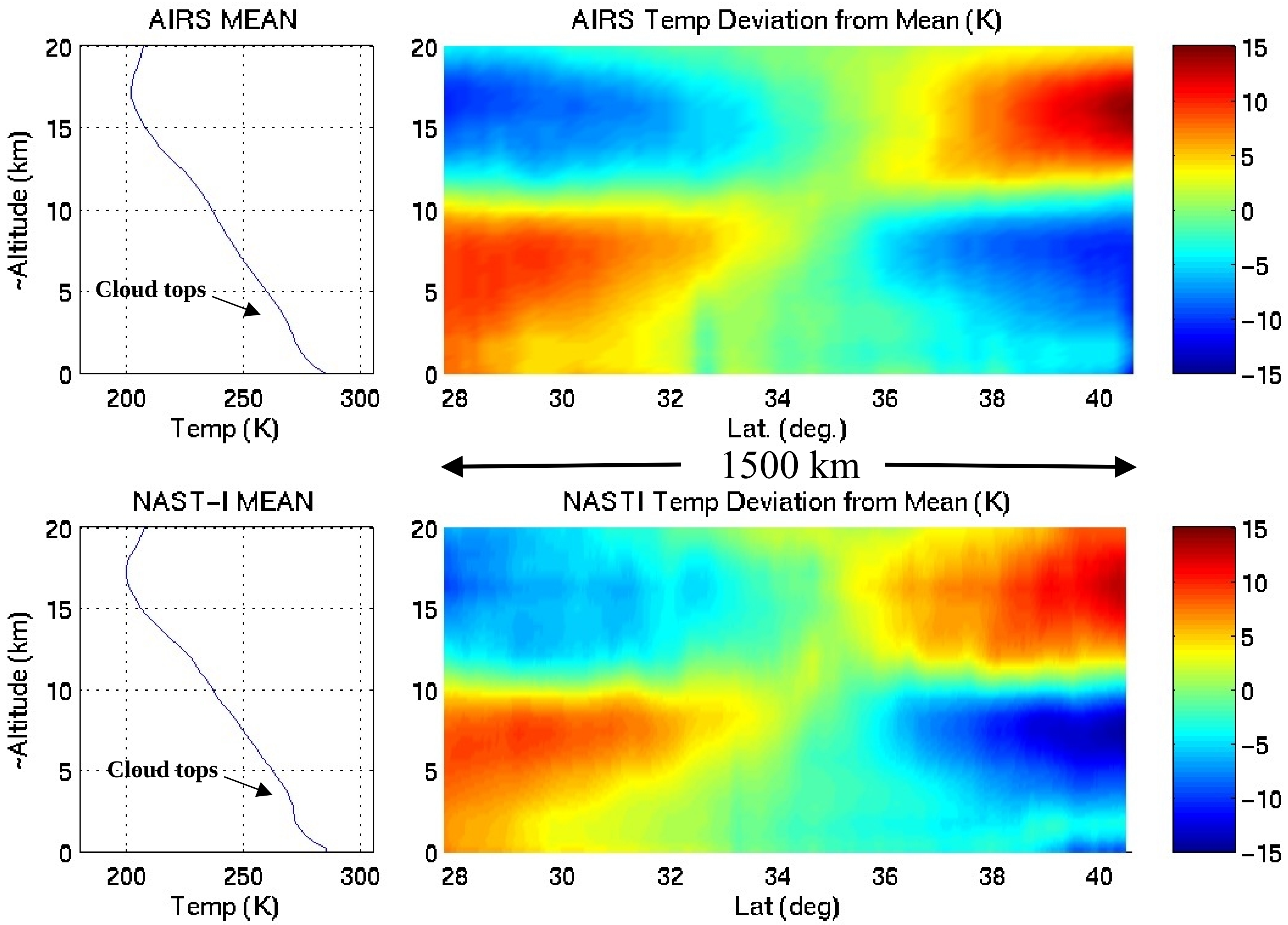
Temperature Deviation (March 11/12, 2003)



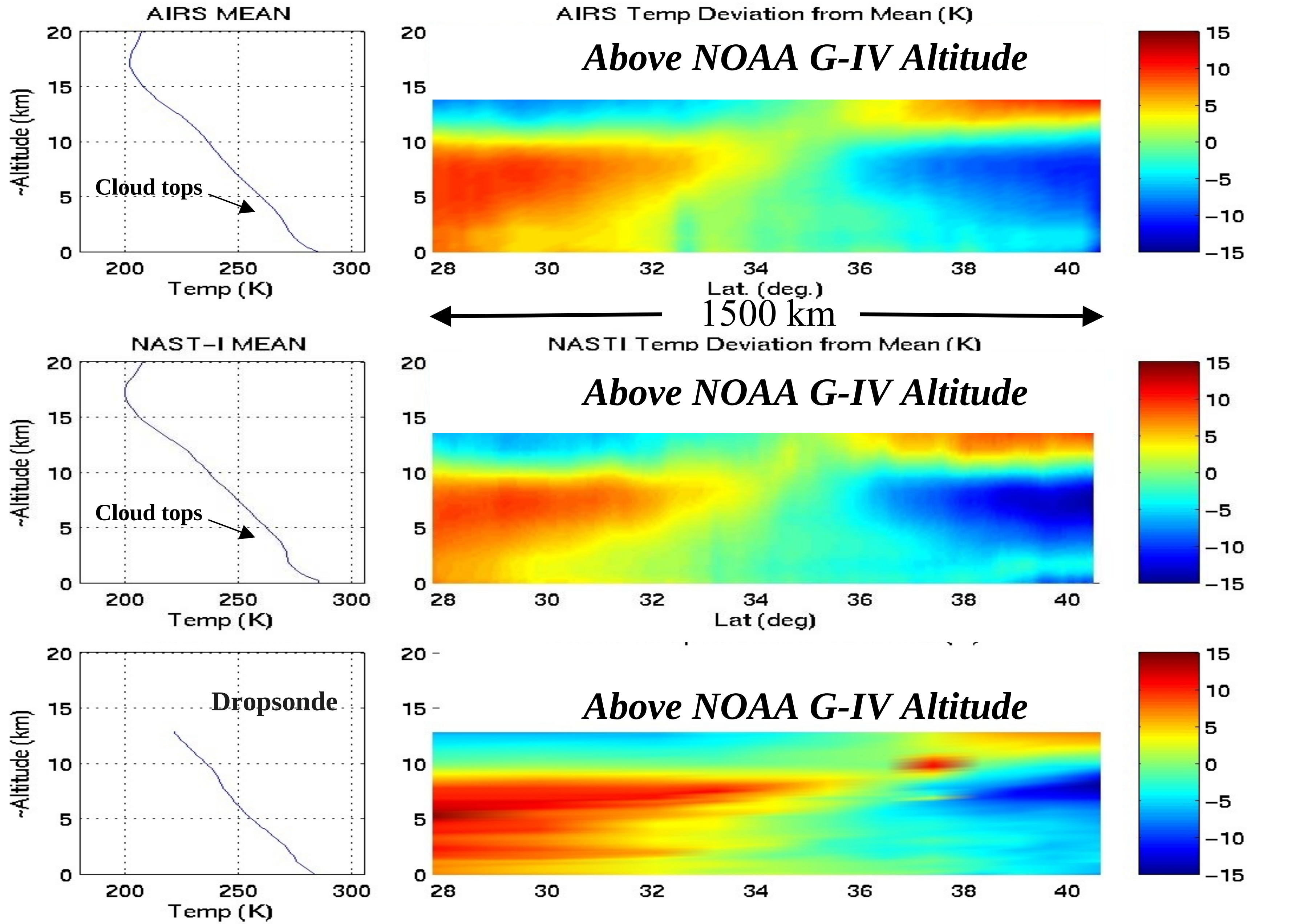
Aqua Overpass Flight (March 12/13, 2003)



Retrieval Comparisons (Deviation from the Mean)



Retrieval Comparisons (Deviation from the Mean)



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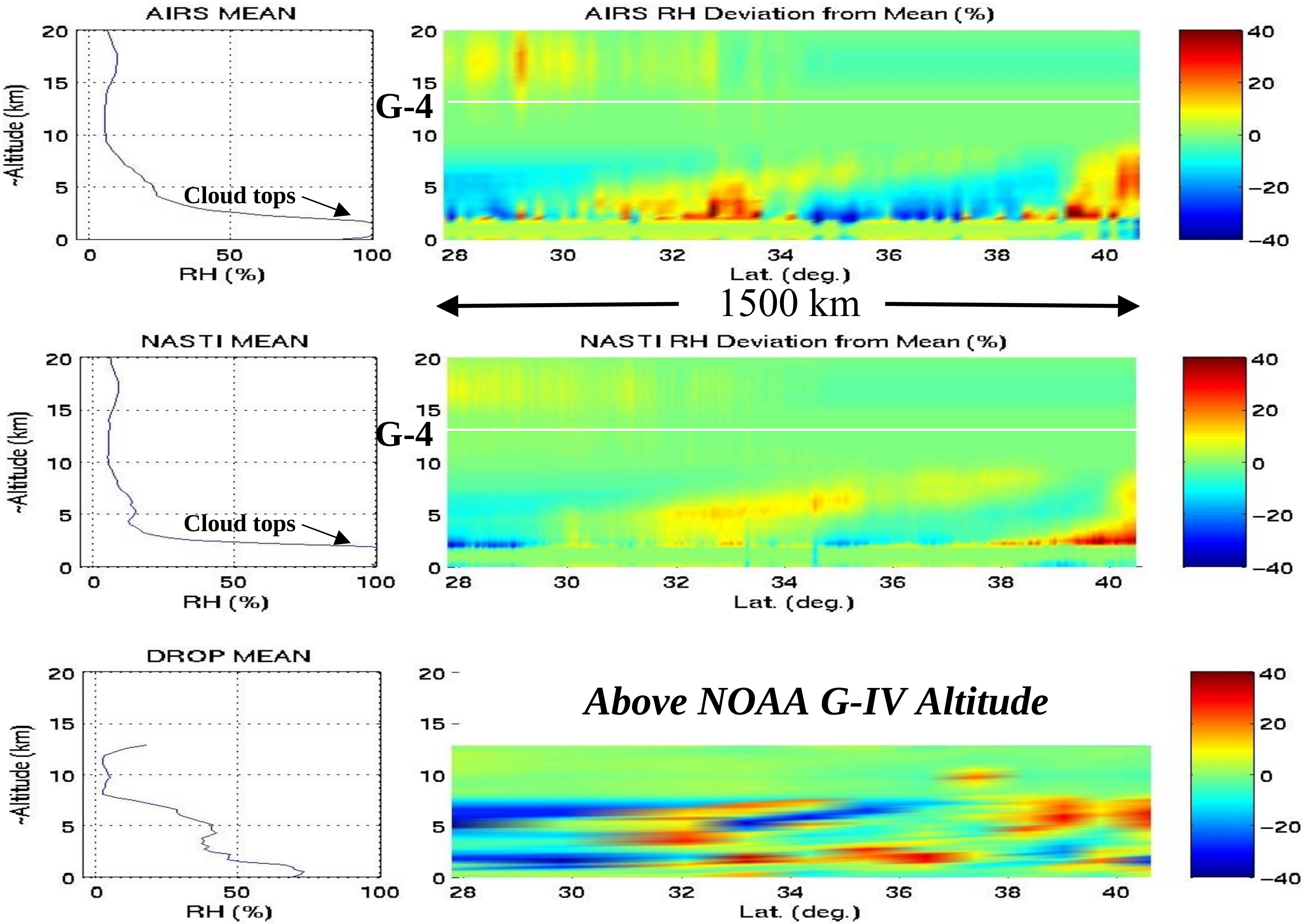
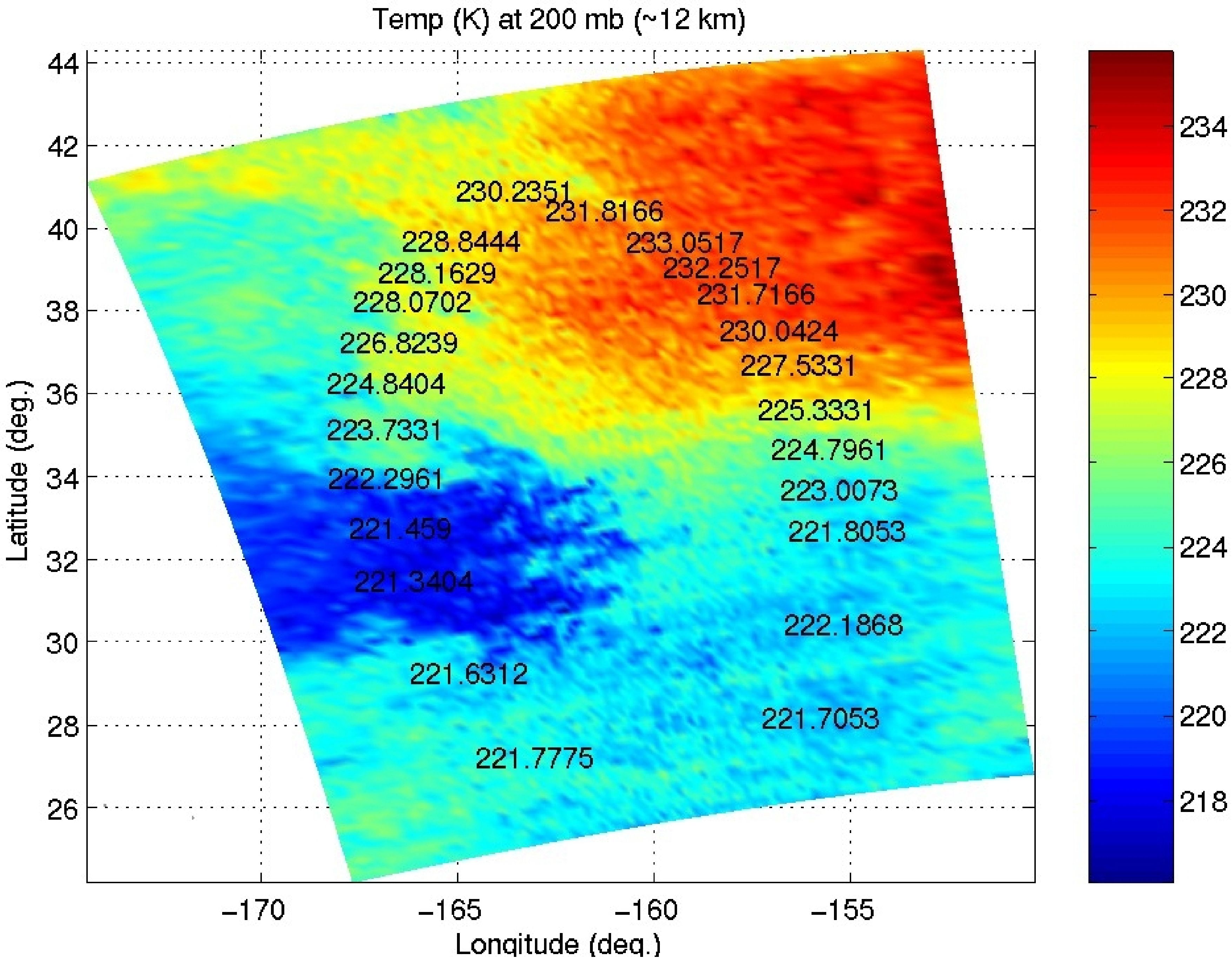
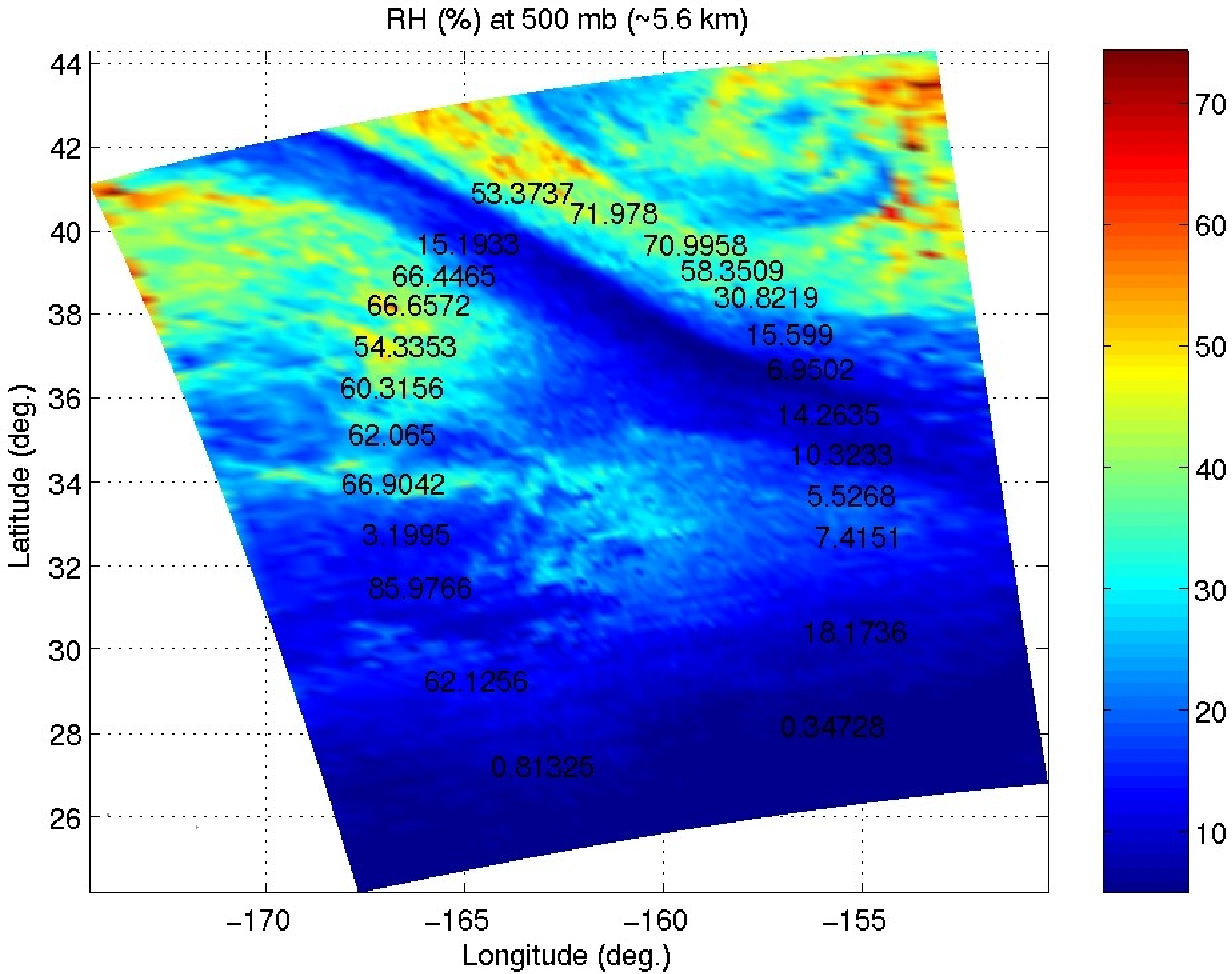




Temp (K) at 200 mb (~12 km)
230.2351
231.8166
228.8444
233.0517
228.1629
232.2517
228.0702
231.7166
226.8239
230.0424
227.5331
224.8404
225.3331
223.7331
224.7961
222.2961
223.0073
221.459
221.8053
221.3404
222.1868
221.6312
221.7053
221.7775
Latitude (deg.)
Longitude (deg.)
44
42
40
38
36
34
32
30
28
26
−170
−165
−160
−155
234
232
230
228
226
224
222
220
218



RH (%) at 500 mb (~5.6 km)
Latitude (deg.)
Longitude (deg.)
44
42
40
38
36
34
32
30
28
26
−170
−165
−160
−155
70
60
50
40
30
20
10
53.3737
71.978
15.1933
70.9958
66.4465
58.3509
66.6572
30.8219
54.3353
15.599
6.9502
60.3156
14.2635
62.065
10.3233
66.9042
5.5268
3.1995
7.4151
85.9766
18.1736
62.1256
0.34728
0.81325

Conclusions

- *AIRS provides high vertical resolution sounding information*
- *The vertical structure radiance signal is small (<0.2 K)*
- *The vertical structure signal is raised above the noise by compressing 1000s of spectral radiances into 10s of pieces of independent information (e.g., amplitudes of radiance covariance eigenvectors). This results in a large S/N advantage [e.g., sqrt(1500/30) $\simeq$ 7]*
- *High vertical resolution soundings can be retrieved down to cloud level by including cloud effects in the formulation of the retrieval algorithm (e.g., include clouds in the training of the EOF regression algorithm)*
- *Small scale horizontal features are resolved in AIRS full spatial resolution soundings*

***The challenge for NWP**: to capture the high spatial resolution sounding signal, for both the clear and the clouded atmosphere*